RADAR POLARIMETRY

POLARIMETRIC AIRBORNE SAR SENSORS

AES1
InterMap Technologies (D)
GulfStream Commander
X-Band (HH), P-Band (Quad)

AIRSAR
NASA / JPL (USA)
DC8
P, L, C-Band (Quad)

AuSAR - INGARA
D.S.T.O (Aus)
DC3 (97) KingAir 350 (00) Beach 1900C
X-Band (Quad)

DOSAR
EADS / Dornier GmbH (D)
DO 228 (89), C160 (98), G222 (00)
S, C, X-Band (Quad), Ka-Band (VV)

ESAR
DLR (D)
DO 228
P, L, S-Band (Quad)
C, X-Band (Sngl)

EMISAR
DCRS (DK)
G3 Aircraft
L, C-Band (Quad)

MEMPHIS / AER II-PAMIR
FGAN (D)
Transal C160
Ka, W-Band (Quad) / X-Band (Quad)

STORM
UVSQ / CETP (F)
Merlin IV
C-Band (Quad)

PHARUS
TNO - FEL (NL)
CESSNA – Citation II
C-Band (Quad)

PISAR
NASDA / CRL (J)
GulfStream
L, X-Band (Quad)

RAMSES
ONERA (F)
Transal C160
P, L, S, C, X, Ku, Ka, W-Band (Quad)

SAR580
Environnement Canada (CA)
Convair CV-580
C, X-Band (Quad)

+ CASSAR (China), MIT/Lincoln Lab (USA), P3-SAR (NADC / ERIM -USA), Military Systems …

RADAR POLARIMETRY

AIRSAR JPL

DC8

P, L, C-Band (Quad)

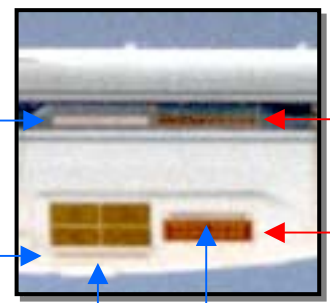
RADAR POLARIMETRY

AIRSAR JPL

AIRSAR is a multi-frequency, quad-polarization, multi-baseline interferometric imaging radar.

Radar	C band	L band	P band
Frequency	5.3 GHz	1.3 GHz	440 MHz
Power	700 W	4 kW	2 kW
Noise-Equiv. sigma0	-35 dB	-45 dB	-48 dB
Polarimetry	Quad	Quad	Quad
Interferometry	XTI, ATI	XTI, ATI	-------
Height Accuracy	1m / 5m	2m / 10m	-------
Velocity Accuracy	10 cm/s	4 cm/s	-------

20 meter baseline for L-band ATI



2.5 meter baseline for C-band XTI

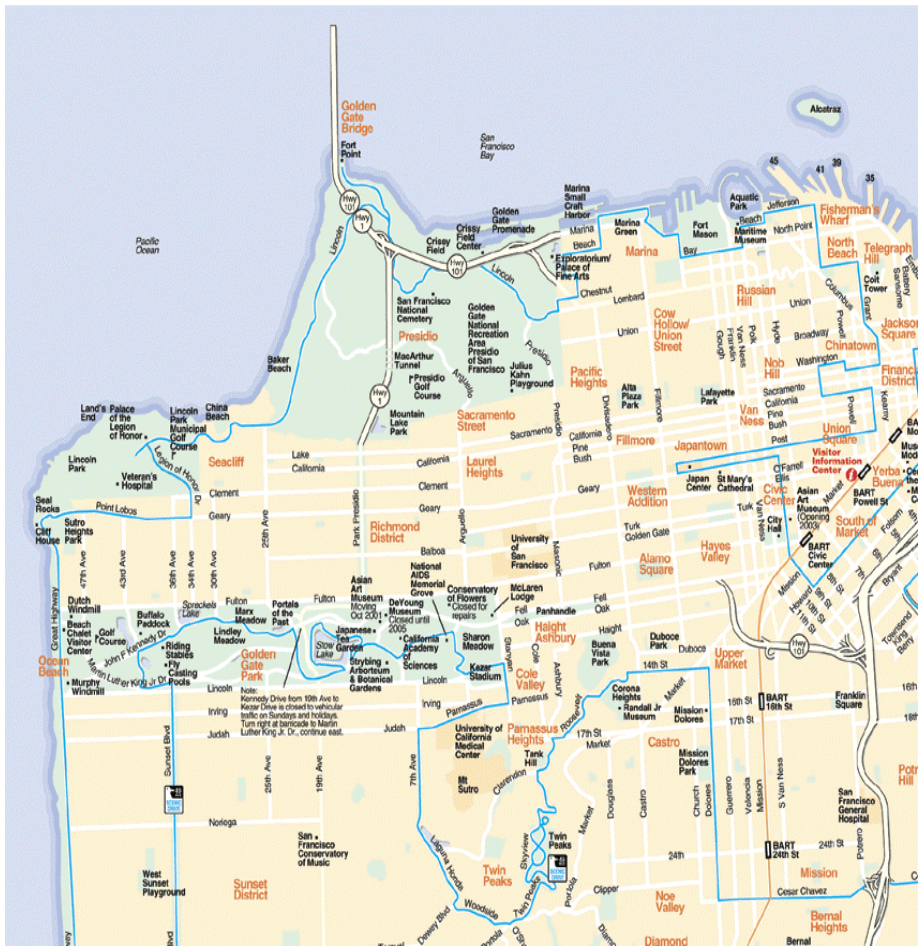
2 meter baseline for L-band XTI

2.0 meter baseline for C-band ATI

Bandwidth	20 MHz	40 MHz	80 MHz
Radar	C/L/P	C/L/P	L
Data Posting	10 meters	5 meters	3 meters
Number of Looks	18	9	5
Swath	20 km	10 km	6 km

RADAR POLARIMETRY

AIRSAR JPL



|HH+VV| |HV | |HH-VV|

San Francisco Bay (1988) – (L-Band)

RADAR POLARIMETRY

AuSAR - INGARA

BEACH 1990 C
X-Band (Quad)

AuSAR – Ingara DSTO Multi-Sensor ISR Test Bed

Courtesy of

AuSAR – Ingara System History

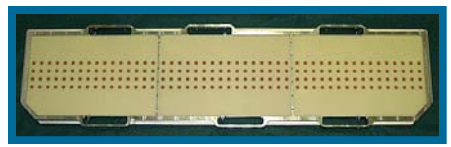
- Radar System First Flewin March 1993
- Has been fitted to three aircraft:
  - DC3 1993 to 1997
  - King Air 350 1998 to 2000
  - Currently integrated into a Beach 1900C as part of the DSTO Multi - Sensor ISR Test Bed program

Courtesy of

RADAR POLARIMETRY

Imaging Radar – DSTO Ingara Multi Mode Radar

ATI



Multi-Pol

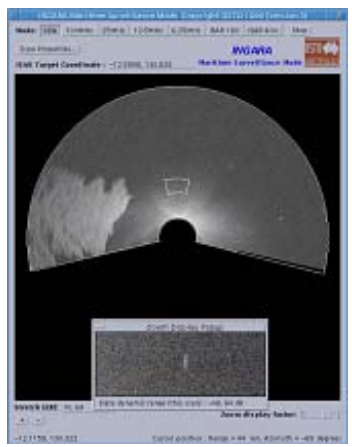
Characteristics

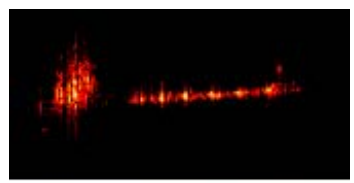
- X-Band (10.1 GHz)
- 2 Receive Channels Along Track Interferometry (ATI)
  or Fully Polarimetric Antenna
- Incidence Angles 45º-89º

Modes:

- Stripmap SAR: 12 km swath, 2 m resolution
- Spotlight SAR: < 1 m resolution
- Moving Target Indicator
- Maritime Scan
- Inverse SAR

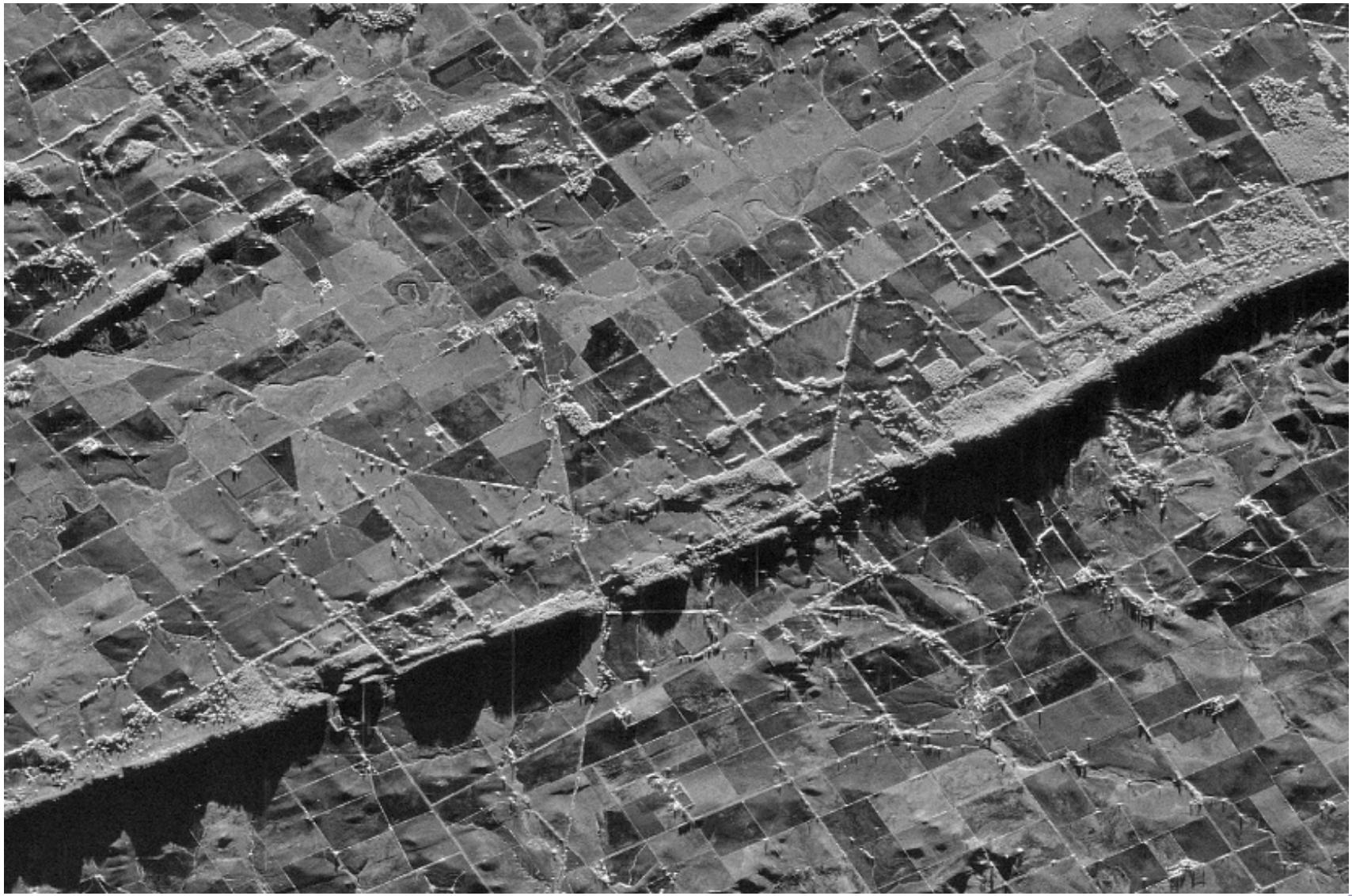
Interferometry SAR Cross Track Interferometry (repeat pass)
ATI for slow moving targets





Courtesy of

RADAR POLARIMETRY



INGARA Image of Saddleworth SA, 1993

Courtesy of

RADAR POLARIMETRY

ESAR

DO 228
P, L, S-Band (Quad)
C, X-Band (Sngl)

P-Band

X-Band

L-Band

C-Band

Courtesy of DLR

RADAR POLARIMETRY

DLR-ESAR Radar System

Do-228 Aircraft Mounted

5 Frequency

Polarimetric/Interferometric

Imaging Radar

ESAR Radar Parameter	X-Band	C-Band	S-band (Late '99)	L-Band	P-Band (*Upgraded)
Pulse Bandwidth	**50/100**	**50/100**	**50/100**	**50/100**	**18/60***
Forward Velocity	**80-95 ms^{-1}**	**80-95 ms^{-1}**	**80-95 ms^{-1}**	**80-95 ms^{-1}**	**80-95 ms^{-1}**
PRF (Hz/channel)	**1600**	**1600**	**400**	**400**	**400**
Flight Altitude	**3-5 km**	**3-5 km**	**3-5 km**	**3-5 km**	**3-5 km**
Incidence Angles	**25-60**	**25-60**	**25-60**	**25-60**	**25-60**
Inteferometric Modes	**Single Pass**	**Repeat Pass**	**Single Pass**	**Repeat Pass**	**Repeat Pass**
Across-Track Baseline	**1.62**	**variable**	****	**variable**	**variable**
Baseline tilt	**12.4 degrees**	**variable**	****	**variable**	**variable**
Along Track Baseline	**0.87m**	*	??	**1.15m**	*
Polarimetric Modes	**Single-Pol**	**Single-Pol**	**Quad-Pol**	**Quad-Pol**	**Quad-Pol**
POLARIMETRIC INTERFEROMETRY	**NO**	**NO**	**YES**	**YES**	**YES**

OBERPFAFFENHOFEN-AIRFIELD

|HH+VV| |HV | |HH-VV|

Oberpfaffenhofen Airfield – (L-Band)

Courtesy of DLR

RADAR POLARIMETRY

EMISAR

DCRS (DK)

G3 Aircraft

L, C-Band (Quad)

RADAR POLARIMETRY

EMISAR

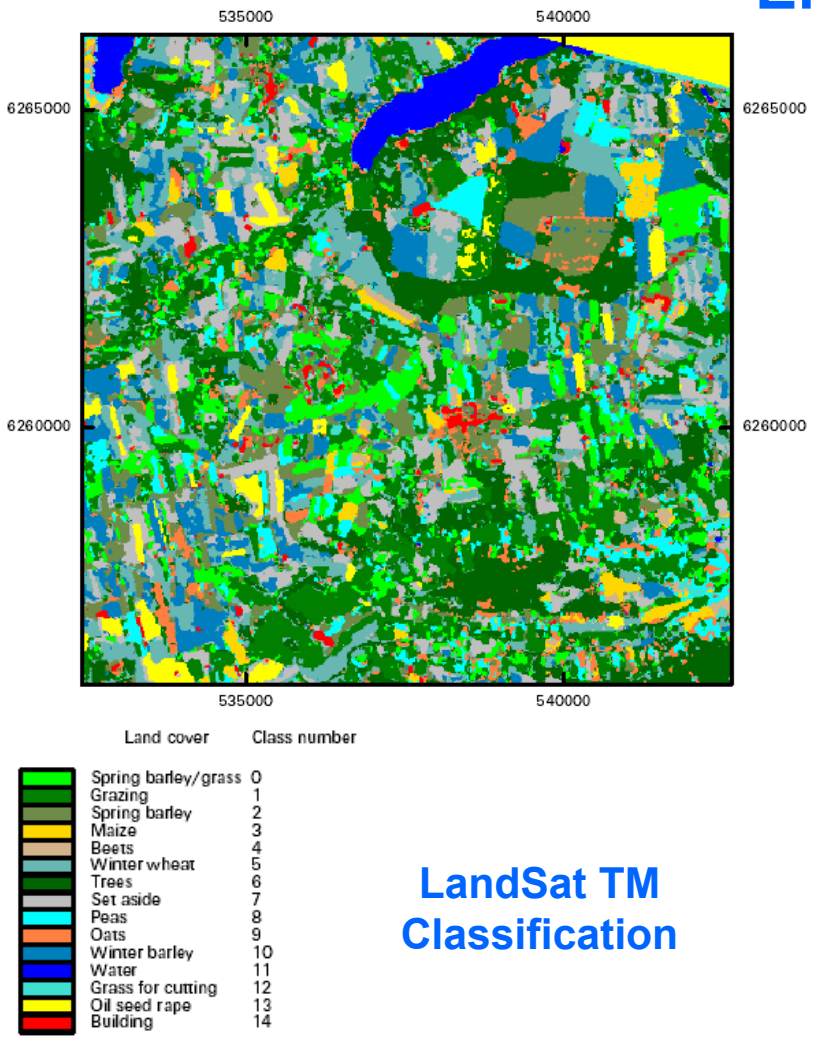
System Parameters		
Frequency	C-Band, 5.3 GHz	L-Band 1.25 GHz
TWT output power	2 kW	6 kW
Receiver noise figure	1.5 dB	1.5 dB
System loss (Tx + Rx side)	(3.1 + 0.9) = 4.0 dB	4 dB
Pulse length	0.64 - 20 µs	0.64 - 20 µs
Max. bandwidth	100 MHz	100 MHz
Antenna gain	27 dBi	18 dBi
Azimuth 3 dB beam width	2.4°	10°
Elevation pattern width	31°	42°
Polarization	Fully polarimetric	Fully polarimetric
Antenna cross polarization	< -30 dB	< -35 dB
Azimuth ambiguity	< -30 dB	< -30 dB
Resolution in slant range	2, 4 or 8 m	2, 4 or 8 m
Resolution in azimuth	2, 4 or 8 m	2, 4 or 8 m
Swath width	12, 24 or 48 km	12, 24 or 48 km
Flight altitude	Typically 41,000 ft	Typically 41,000 ft
Real-time processing	Full resolution	Full resolution
Range (Noise equivalent $\sigma o < -20$ δB)	Max. 80 km	Max. 64 km
PSLR	-30 dB	-25 dB
ISLR	-28 dB	-21 dB
Intrinsic cross-talk terms	< -30 dB	< -35 dB
Calibrated cross-talk terms	< -35 dB	TBD
Weight, Equipment inside cabin	600 kg	
Pod	240 kg	
Power: 115 V, 400 Hz	5 kW, 6 kVA	
28 V, DC	1 kW	
Dimensions: Equipment inside cabin	3 x 19" racks, H=1.40 m	
Pod	4.59 x 0.81 x 0.55 m	

RADAR POLARIMETRY

Copenhagen (1999)
C-Band

RADAR POLARIMETRY

EMISAR

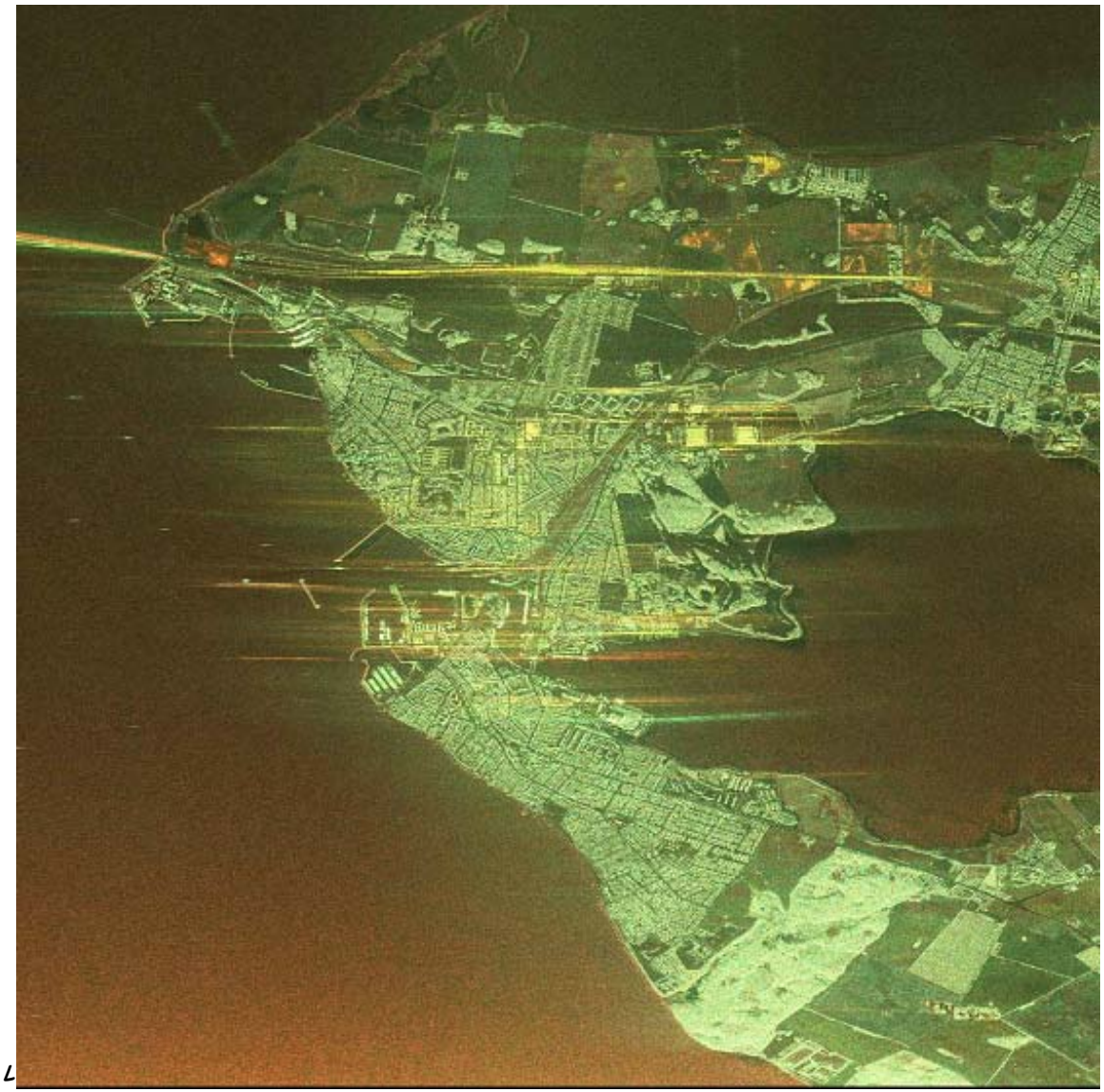


LandSat TM Classification

Foulum (C-Band) Land Cover Monitoring

RADAR POLARIMETRY

EMISAR



RADAR POLARIMETRY

PHARUS

TNO - FEL (NL)

CESSNA – Citation II

C-Band (Quad)

RADAR POLARIMETRY

Parameter	Value	Remarks
Radar type	Coherent pulse radar	
RF carrier frequency	5.3 GHz	
pulse repetition frequency	2000 - 5000 Hz	can be locked to ground speed
pulse length	3.2 - 25.6 μ s	preferred value 12.8 μ s
waveform type	arbitrary	pre-programmed linear FM sweeps for low, medium and high resolution
bandwidth	programmable	45 MHz for high resolution 24 MHz for medium resolution 12 MHz for low resolution upgradeable to 100 MHz
resolution	3 x 3 m max.	in high resolution mode 1m in azimuth for single look
transmit peak power	960 W max.	reduces to 540 W with antenna tapering
polarisation	transmit: H or V receive: H and V	interleaved on transmit optional simultaneous on receive optional
azimuth beamwidth	2.3° (uniform) 3.0° (tapered)	
azimuth scan angle	-20° to +20° in 0.5° steps	
elevation	24°	
elevation scan angle	-15° to 15° in 0.5° steps	
elevation pointing angle	57.5°	reference plane is horizontal
range	26 km	single polarisation, uniform actual range depends on radar-mode
range sampling frequency	100 MHz	8 bits
data storage rate	100 Mbit/s	
platform	Cessna Citation II	PH-LAB
altitude	max. 13 km	
Groundspeed during measurements	90 - 150 m/s	
flight path registration	IRS,GPS,FMS	

resolution (m)	# pol.	# looks	sensitivity (dB)	swath (km)	altitude (km)	max. range (km)
4	4	4	-40	4.4	4.5	8.0
4	4	4	-30	8.0	4.5	14.5
8	4	4	-40	6.5	5.0	11.0
16	4	16	-40	7.9	6.0	13.0
4	1	4	-30	11.2	6.0	16.0
8	1	8	-30	14.6	6.0	20.0
16	1	16	-30	20.0	6.0	26.0
4	1	4	-20	9.9	12.0	18.0
16	1	20	-30	14.9	12.0	22.0
24	2	4	-25	9.8	12.0	20.0

PHARUS

RADAR POLARIMETRY

PHARUS

|HH| |HV| |VV|

Amsterdam (1997)
C-Band

RADAR POLARIMETRY

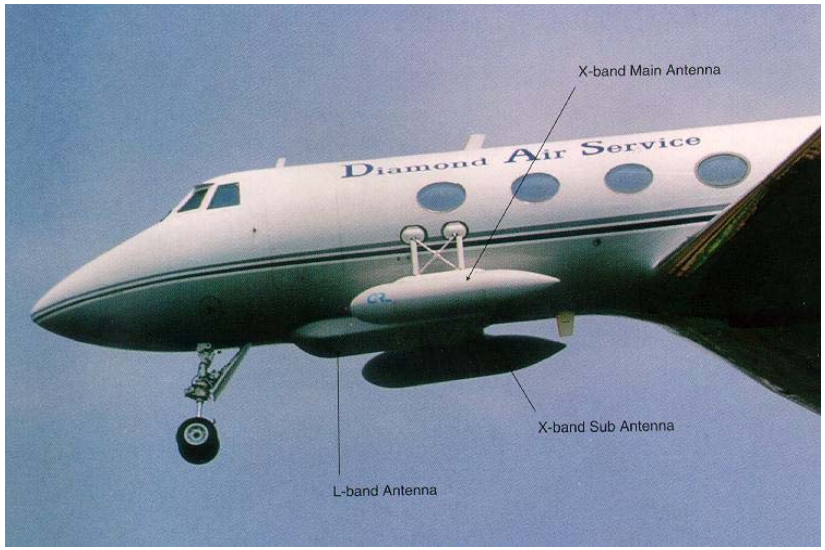
PISAR

NASDA / CRL (J)

GulfStream

L, X-Band (Quad)

RADAR POLARIMETRY



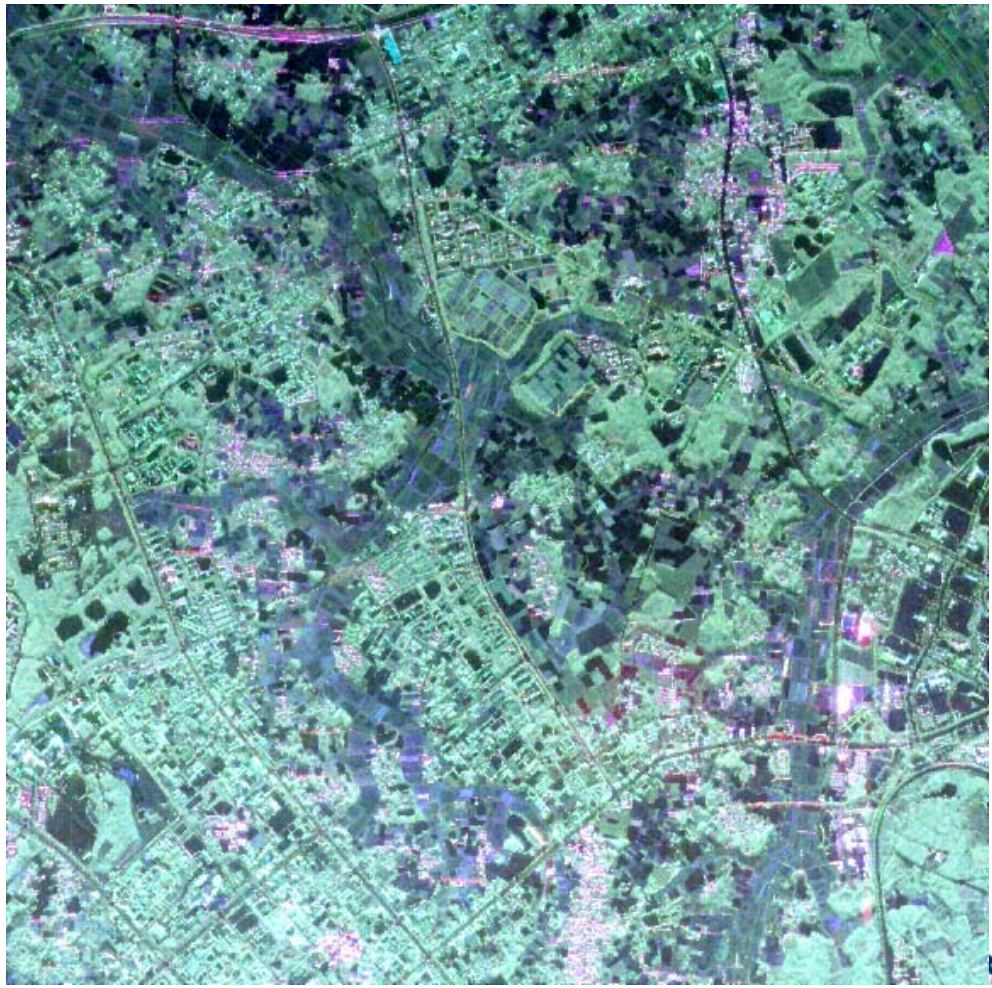
PI-SAR

RADAR POLARIMETRY

PISAR - GULF STREAM II
Altitude: 6000m - 12000m
Speed: 100 m/s - 250 m/s
Size: 24.3 m - 21.3 m

Tsukuba Science City (1997)
L-Band

IMAGE SIZE : 2000 (Range) x 2000 (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)



|HH| **|HV|** **|VV|**

RADAR POLARIMETRY

PISAR - GULF STREAM II
Altitude: 6000m - 12000m
Speed: 100 m/s - 250 m/s
Size: 24.3 m - 21.3 m

Tsukuba Science City (1997)
X-Band

IMAGE SIZE : 2000 (Range) x 2000 (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)

|HH| **|HV|** **|VV|**

RADAR POLARIMETRY

Tsukuba Science City (1997)

L-Band

IMAGE SIZE : 600 (Range) x 600 (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)

X-Band

IMAGE SIZE : 600 (Range) x 600 (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)

RADAR POLARIMETRY

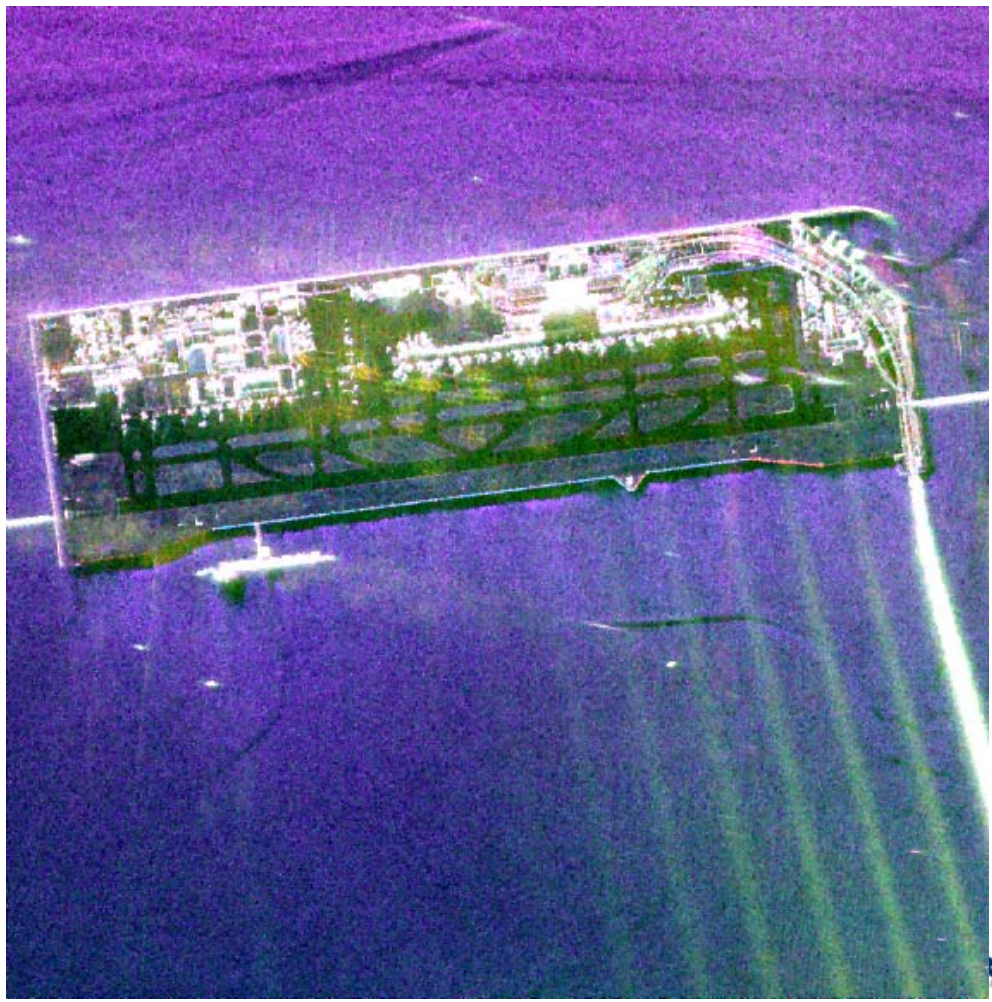
Kansai International Airport

RADAR POLARIMETRY

PISAR - GULF STREAM II
Altitude: 6000m - 12000m
Speed: 100 m/s - 250 m/s
Size: 24.3 m - 21.3 m

Kansai Airport (1997)
L-Band

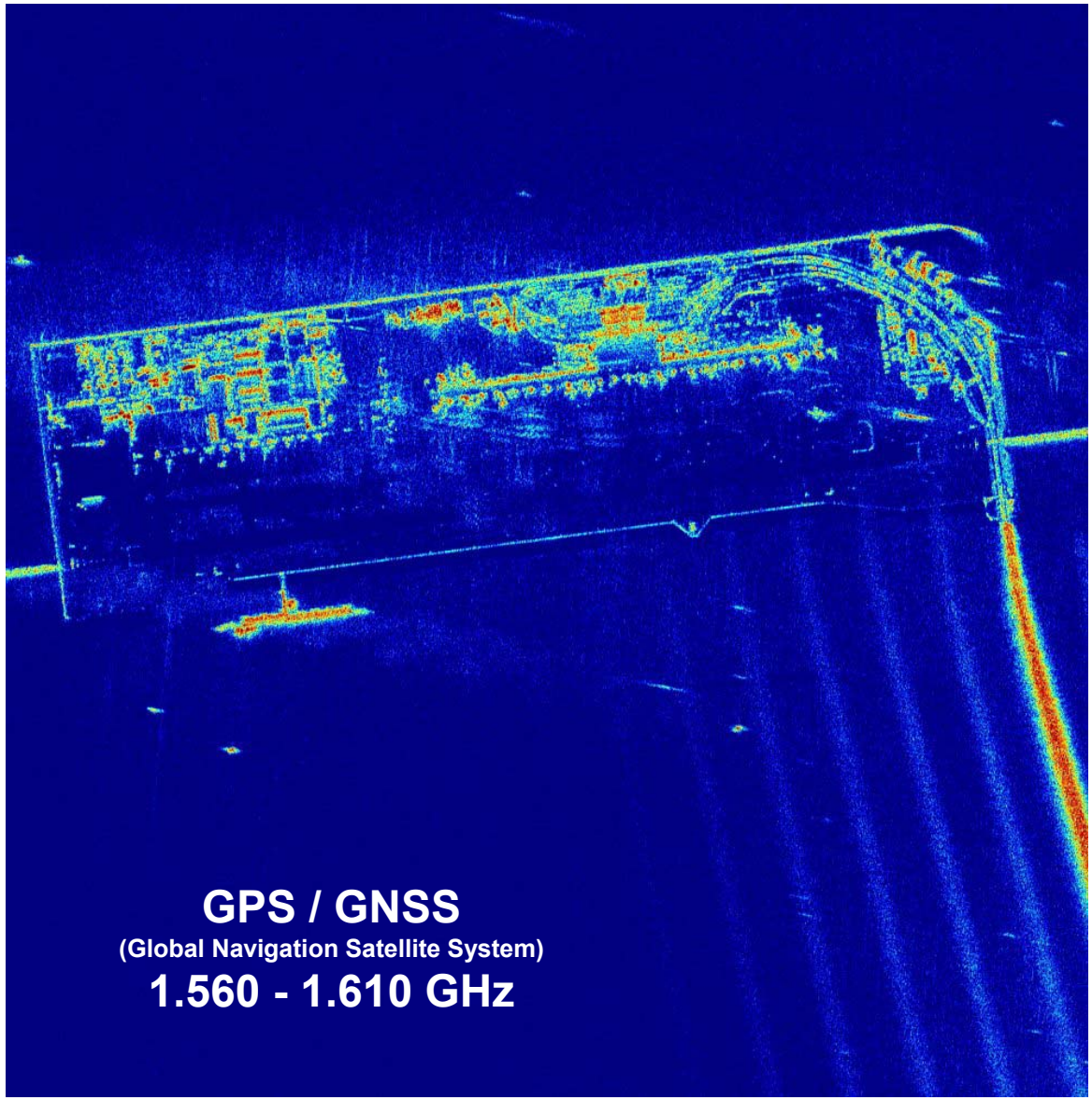
IMAGE SIZE : 2000 (Range) x 2000 (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)



|HH| **|HV|** **|VV|**

RADAR POLARIMETRY

HV



0 dB

-15 dB

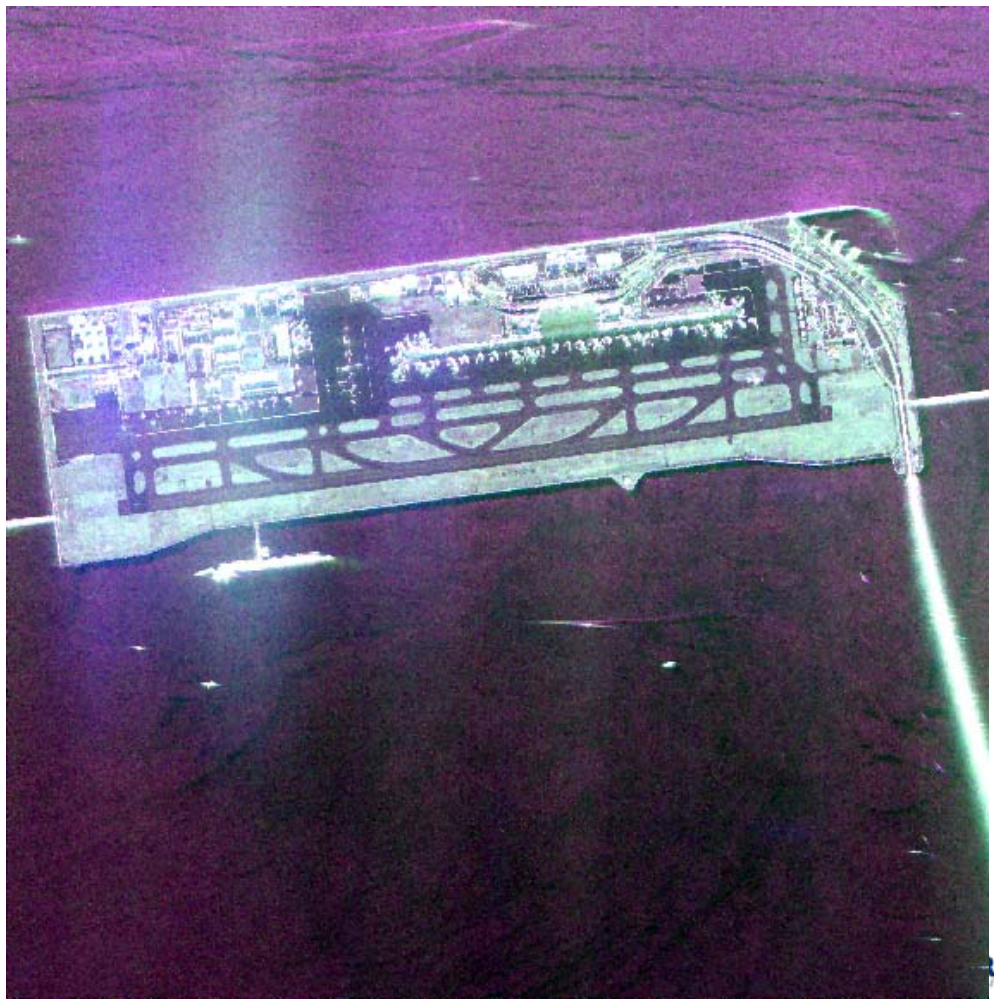
-30 dB

RADAR POLARIMETRY

PISAR - GULF STREAM II
Altitude: 6000m - 12000m
Speed: 100 m/s - 250 m/s
Size: 24.3 m - 21.3 m

Kansai Airport (1997)
X-Band

IMAGE SIZE : 2000 (Range) x 2000 (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)

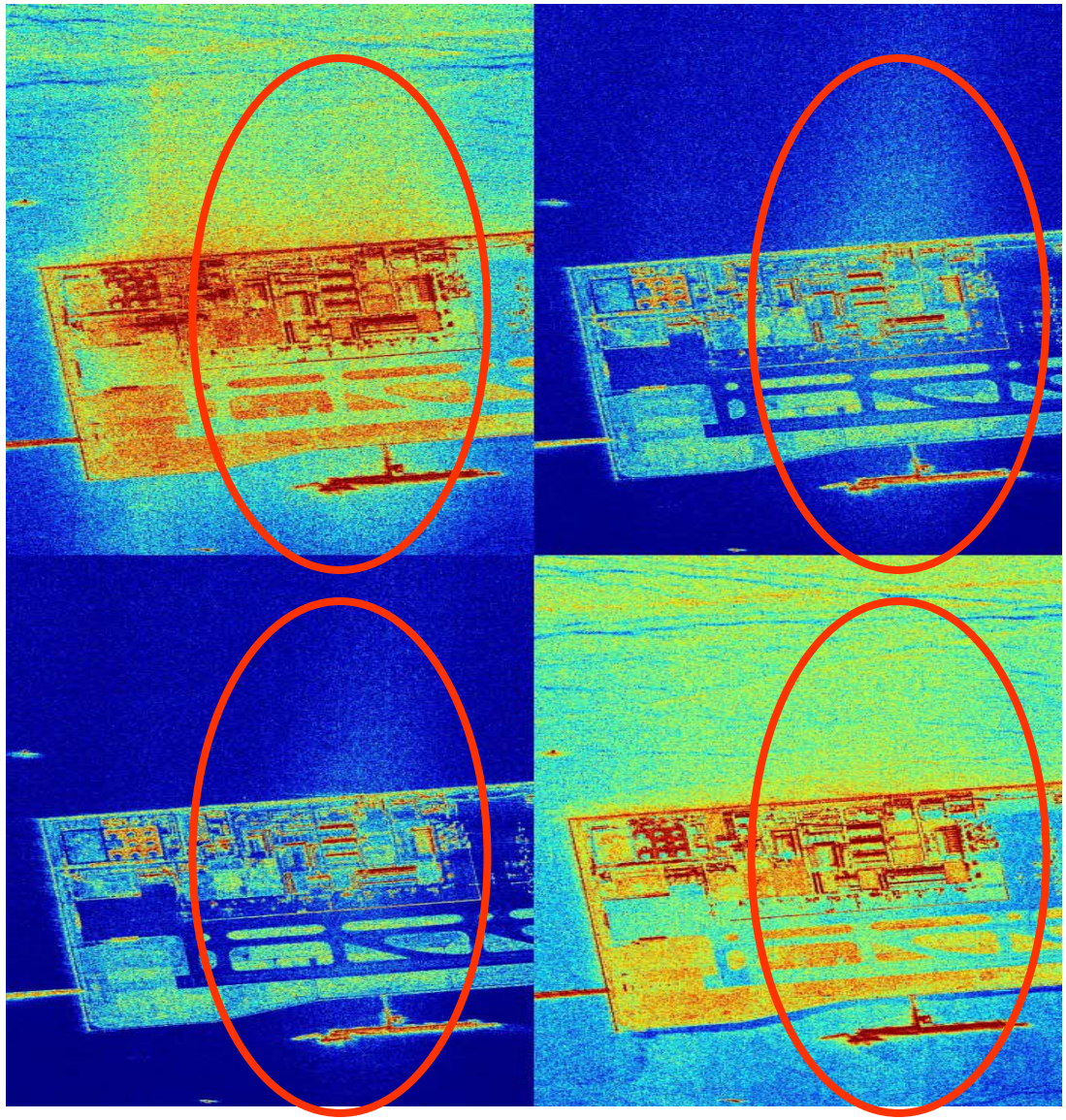


|HH| **|HV|** **|VV|**

RADAR POLARIMETRY

HH

VH



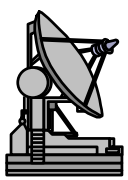
HV

VV

0 dB

-15 dB

-30 dB



A.T.C - X Band
9.0 - 9.2 GHz
Circular Polar

RADAR POLARIMETRY

Tohoku University (2001)

L-Band

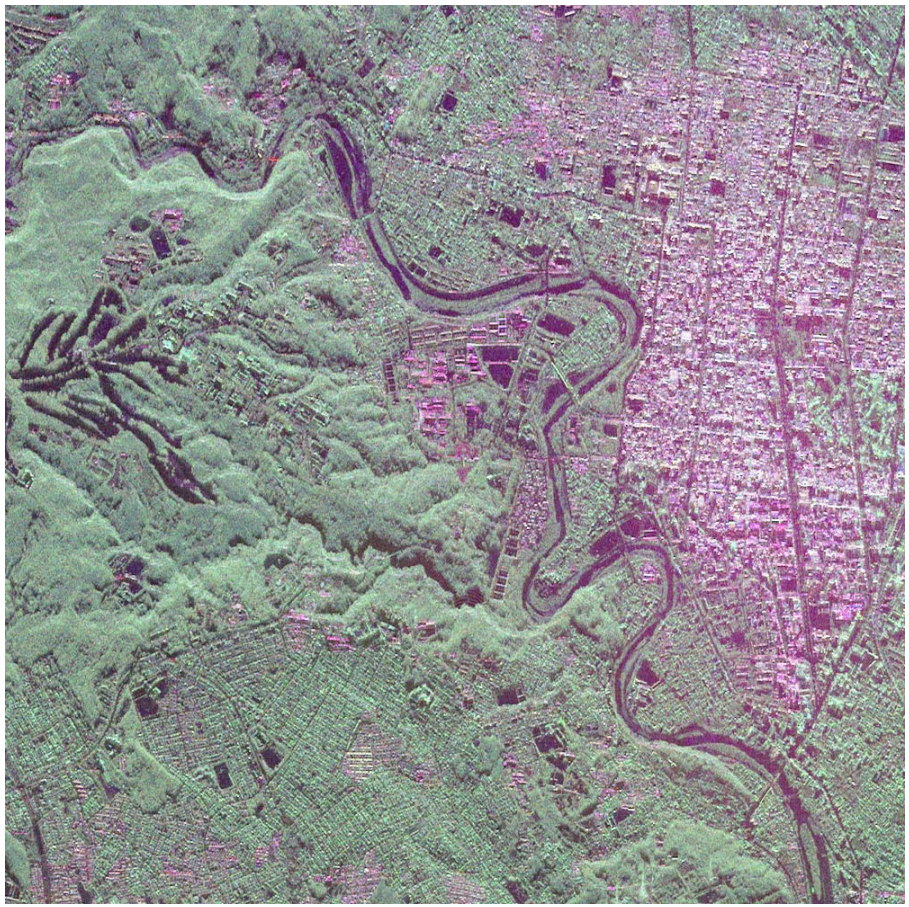


IMAGE SIZE : 5000m (Range) x 5000m (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)

X-Band

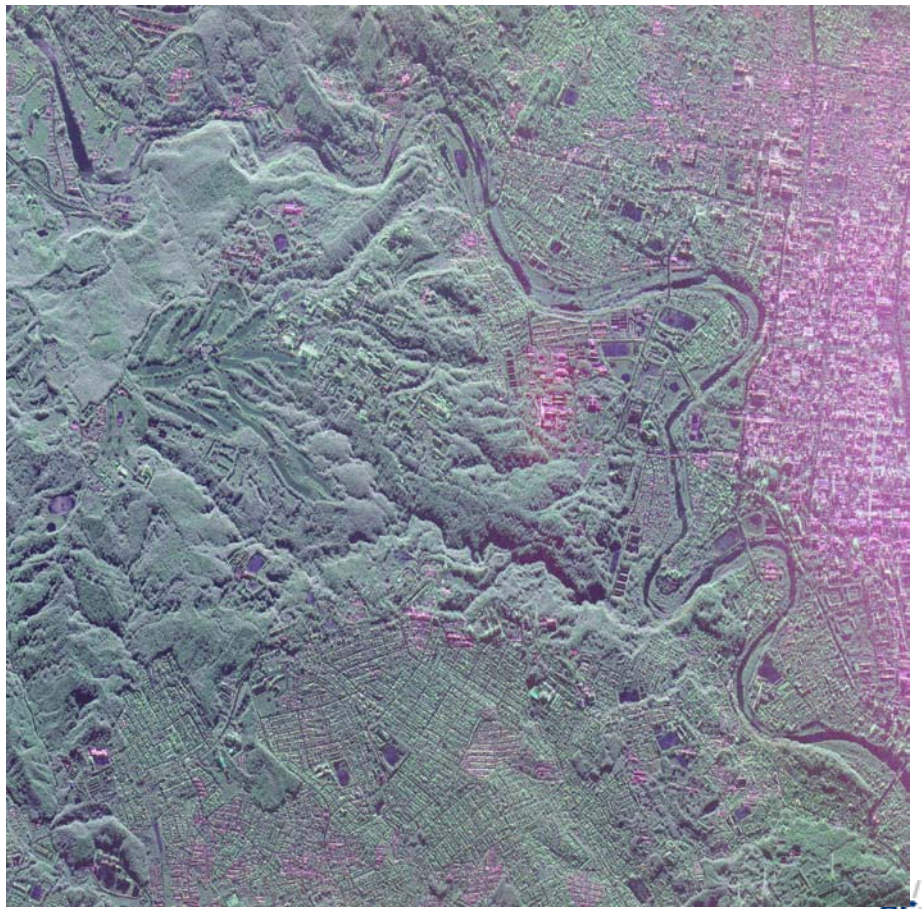
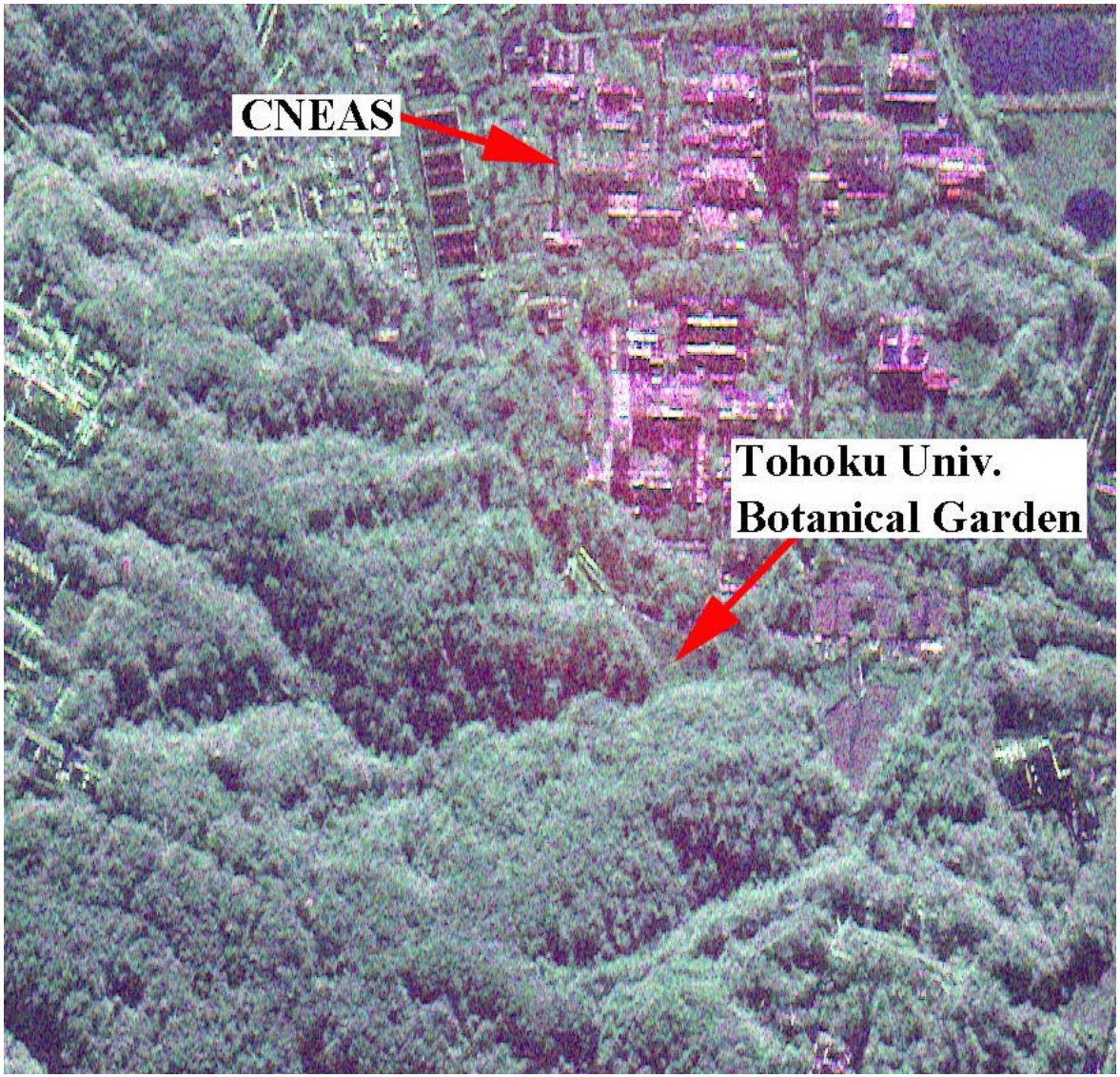


IMAGE SIZE : 5000m (Range) x 5000m (Azimut)
PIXEL SIZE : 2.5m (Range) x 2.5m (Azimut)

RADAR POLARIMETRY



Tohoku University
Kawauchi Campus,
Sendai, Miyagi
(2001) X-Band

RADAR POLARIMETRY

RAMSES

ONERA (F)

Transal C160

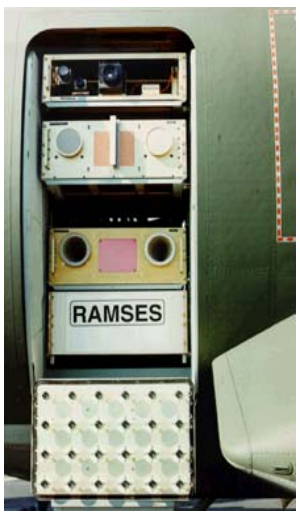
P, L, S, C, X, Ku, Ka, W-Band (Quad)

RADAR POLARIMETRY

MAIN CHARACTERISTICS OF THE RAMSES SYSTEM

Band	Ctr Freq [GHz]	λ [cm]	Bwidth [MHz]	Rés [m]	Anten.	Elev x azimut	Peak Power	Power Stage	Polar	Mode
P	0.43	69,7	75	2	Array	40° x 30°	300	SSA	Full	
L*	1.3	23	200	0,75	Array	23° x 16°	100	SSA	Full	
S	3.2	9,4	300	0,5	Array	30° x 10°	150	SSA	Full	
C	5.3	5,6	300	0,5	Array	33° x 8°	500	TWT	Full	
X	9.6	3,1	1200	0,13	Both	16° x 16°	200	TWT	Full	IFPOL, IF MB
Ku	14.3	2,1	1200	0,13	Horn	14° x 14°	200	TWT	Full	IFPOL, IF MB
Ka	35	0,8	1200	0,13	Horn	20° or 5°	100	TWT	VV	
W	95	0,3	500	0,3	Horn	3° 5° 10° or 20°	50	EIA	LR, LL	

- Boresight incidence angle can be adjusted from 30° to 75°(except at P-band)
- Flexible waveform: Bandwidth, number of recorded channels, swath width
- Two frequencies can be operated simultaneously



Courtesy of ONERA

RADAR POLARIMETRY

RAMSES
X -Band (Quad - PolInSar)
Resolution: 0.9m (range) x 0.9m (azimut)
Swath: 800m

|HH-VV| **|HV |** **|HH+VV|**

Campaign **RITAS** (Radar Imagerie Thématique Agricole et Sols)
INRA, CETP, BRGM, CEMAGREF et ONERA – March 2002

Courtesy of ONERA UNIVERSITE DE RENNES 1

RADAR POLARIMETRY

Bretigny Airport (X-Band)

SAR580

Environnement Canada (CA)

Convair CV-580

C, X-Band (Quad)

Developed by Canada Centre for Remote Sensing CCRS – 1974

Fully Polarimetric SAR at C-Band

Now owned and operated by Environment Canada

Viewed as a primary research tool to support CCRS work for RADARSAT 2 and ENVISAT

SAR580

Environnement Canada (CA)

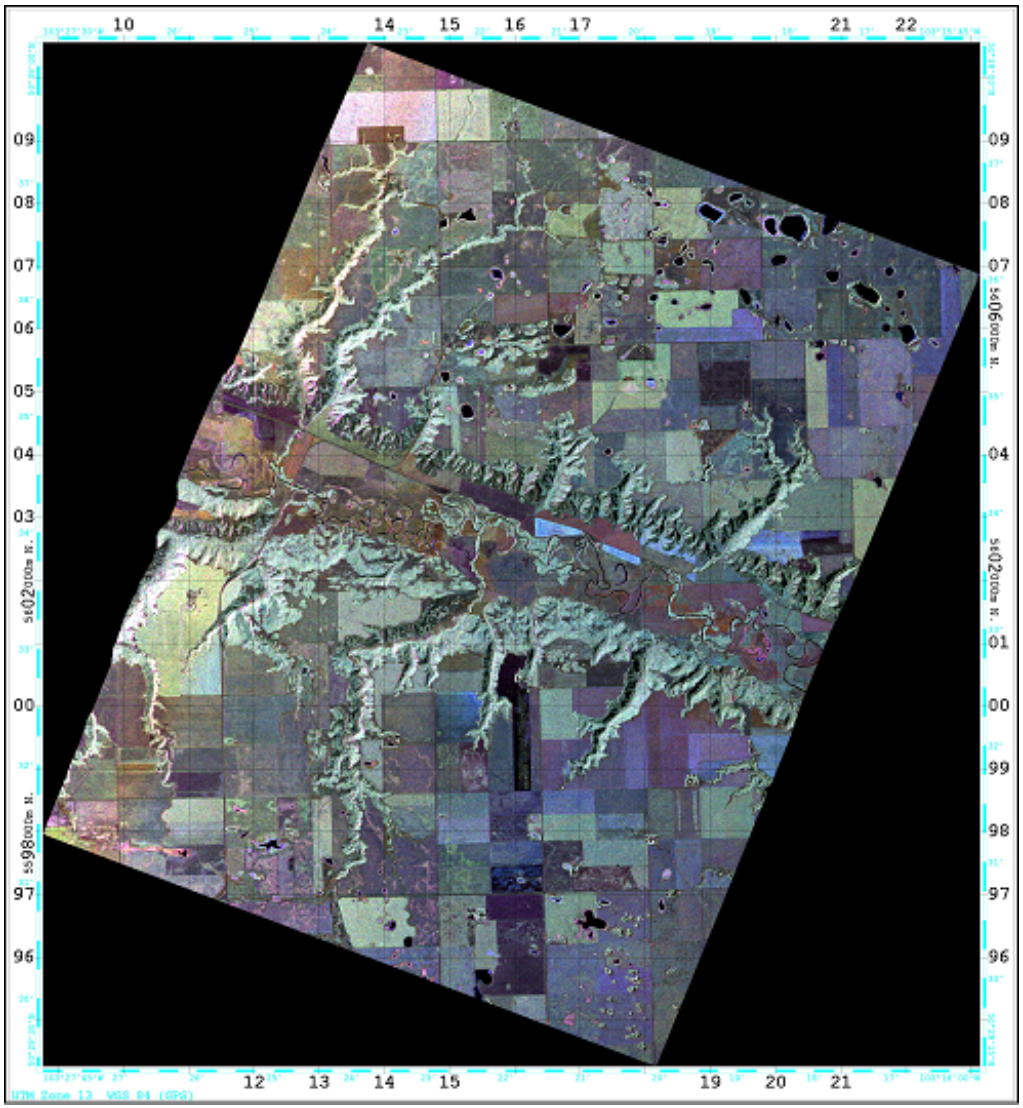
Convair CV-580

C, X-Band (Quad)

Parameter	Units	Value
Antenna		
Polarization		H and V
Peak Gain	dB	27
Elevation Width	°	16
Azimuth Width	°	3
Transmitter		1
		TWT
Chirp Generation		SAW
Power	kW	16
Frequency	GHz	5.3
PRF/V	1/m	3.32 or 2.57
PRF_max	Hz	383x2
Receivers		2
Compression		SAW^{-1}
Digitization		I +Q
		6-bit

RADAR POLARIMETRY

SAR580



Qu'Appelle River
(June 2000)
Geocoded Product